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Increased Velocity Exercise Specific to Task Training Versus the National Institute on Aging's Strength Training Program: Changes in Limb Power and Mobility

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Background. This study was designed to evaluate the benefits of InVEST (Increased Velocity Specific to Task) training on limb power and mobility among mobility-limited older adults.

Methods. We conducted a single blinded, randomized controlled trial among 138 mobility-limited community-dwelling older adults, evaluating two 16-week supervised exercise programs. The intervention group participated in InVEST training, and the control group participated in the National Institute on Aging's (NIA) strength training program. Primary outcomes were changes in limb power per kilogram and mobility performance as measured by the Short Physical Performance Battery (SPPB).

Results. After 16 weeks, InVEST produced significantly greater improvements in limb power than NIA (p = .02). There was no significant difference in strength improvements. Both groups had significant changes in SPPB of greater than 1 unit. Self-reported function was also significantly improved in both groups. Differences between groups were not statistically different. In a post hoc analysis when participants were categorized by the manifestation of baseline leg velocity impairments (N = 68), InVEST training produced effect size differences in SPPB that were clinically meaningful (SPPB Group × Time difference 0.73 units, p = .05).

Conclusions. Among mobility-limited older adults, both NIA and InVEST produce robust changes in observed physical performance and self-reported function. These improvements were not meaningfully different by statistical or clinical criteria. Compared with NIA, InVEST training produced greater improvements in limb power and equivalent improvements in strength. Observed differences between NIA and InVEST based upon baseline leg impairment status are informative for futures studies.

Key Words: Exercise—Rehabilitation—Mobility—Muscle power—Task performance.

FUNCTIONAL enhancement has been the basis of nationally advocated exercise programs like that provided by the National Institute on Aging (NIA), which emphasizes progressive resistance training (1). However, improvements in physical functioning have been observed in only a subset of appropriately designed studies (2). Two elements of exercise training not emphasized within nationally advocated exercise programs include muscle power and task specificity (1,3). Recent investigations have highlighted the relevance of both elements to older adults with mobility problems (4–6).

Muscle power is defined as muscular work per unit of time and is the product of force (strength) and velocity (speed) of movement (2). Limb muscle power is linked to functional limitations, disability, and falls (7–9). Despite improvements in muscle power with high-velocity, "explosive" training (10), the appropriate exercise equipment is commonly not available to the vast majority of older adults.

Pilot studies evaluating simpler, more cost-effective forms of power training that emphasize task specificity reported improvements in muscle power and physical functioning (4,11). Task specificity refers to the idea that training should mirror the functional activity for which a person is training. The exercise program in these studies, known as InVEST (Increased Velocity Exercise Specific to Task) training, did show promise as a safe, simple mode of exercise enhancing muscle power and functional performance.

Therefore, we compared the benefits of the NIA and the InVEST exercise training programs on improvements in muscle power and functional performance among community-dwelling older adults whose mobility status placed them at risk for disability. We hypothesized that after 16 weeks of training: (a) InVEST would produce significantly greater improvements in limb muscle power than NIA; (b) both programs would produce significant changes in mobility limitation from baseline; but (c) significantly greater improvements would be observed among the InVEST participants.

Methods

This single blinded, randomized controlled trial was conducted at two outpatient rehabilitation facilities in the greater Boston area. The Institutional Review Boards at Hebrew SeniorLife, Harvard Medical School, and the Spaulding Rehabilitation Hospital Network approved the conduct of the study.

Recruitment of Participants

Initially, inquiries were solicited via research volunteer registries, advertising in newspapers, direct mailings, and referrals from primary care providers, resulting in 493 telephone screenings. Of these, 265 people were identified as potentially eligible and attended an initial screening assessment.

Screening Process

Participants included in the study were community-dwelling older adults (age ≥ 65 years) with Short Physical Performance Battery (SPPB) scores between 4 and 10 who were able to climb a flight of stairs independently or using a device (eg, cane). This ensured that our study participants manifested mobility limitations (12) and were able to safely undergo our extensive physical performance testing. Exclusion criteria were unstable acute or chronic disease, a score of less than 23 on the Mini-Mental State Examination (13), a neuromusculoskeletal impairment limiting participation in further performance testing, participation in a resistance training program, or a submaximal treadmill exercise tolerance test with positive findings for unstable cardiovascular disease.

After providing informed consent, participants underwent a comprehensive history and physical examination conducted by one of the authors (J.F.B.). At the completion of the physical examination, all active medical conditions and medications were recorded for each participant. Medical records were requested from participants' primary care physicians to corroborate these findings. Depression was defined as a score of 16 or more on the Center for Epidemiological Studies-Depression Scale (14). Assessments were completed during one to two subsequent baseline visits depending on participant availability. On completion of the initial screening, 99 people could not participate in the study due to exclusion criteria, and 28 chose not to commit to the study. Initial power estimates assuming beta = .2 and alpha = .05, required recruitment of 138 persons (63 per group and 10% attrition) with the expectation of an observed 25% difference in limb power, utilizing a two-tailed *t* test of equal variance.

Randomization

A total of 138 participants were randomized into the two treatment groups. Randomization was stratified by gender using a computer-generated block randomization scheme of variable block size.

Interventions

Both the exercise groups participated in exercise sessions that lasted 45–60 minutes and had identical protocols for warm-up and cool-down activities and monitoring of exercise intensity. Small-group exercise sessions (two to five people) were provided 3 d/wk (every other day) in the gym of an outpatient rehabilitation center under the direction of a certified exercise trainer. Both groups included exercises addressing the major muscle groups of the upper (eg, muscles acting upon the elbow and shoulder) and lower extremities (eg, muscles acting upon the ankle, knee, and hip) as well as the trunk. Exercise intensity was monitored using the Borg Scale of perceived exertion (RPE) (15). Target for exercise intensity was RPE between 11 and 16 on the Borg Scale. Exercise was stopped or resistance reduced if an individual achieved an RPE of 17 or more or a heart rate that was greater than or equal to 85% of age-predicted maximum. Resistance was increased when RPE values fell below the targeted range. Progression and technique were modified and exercises were skipped if an individual experienced any persistent physical complaints. Maintenance of safe positioning, posture, and form was provided by reinforcement from the trainer during exercise. Both groups performed exercises in a seated position or using a chair or rail for support. Neither group performed exercises using special exercise machines, but rather resistance was applied using either weighted vests (InVEST training) or free weights (NIA training).

The InVEST training program consisted of a series of exercises that were conducted while wearing a weighted vest. Resistance progressed in 2% body weight increments, and weight was distributed evenly within the vests. In contrast to the NIA, which focuses on isolating specific muscle groups, all InVEST exercises (see Appendix) emphasize a task-specific movement pattern rather than the isolation of a specific muscle group. For all exercises, the concentric action (shortening portion) was performed as quickly as possible while maintaining good form, followed by a 1-second pause and then the eccentric action (lengthening portion) completed during 3 seconds. All exercises were performed in two sets. By design, stair climbing exercise was not initiated until after Week 4 and was only allowed once an individual demonstrated the ability to ascend and descend two flights of stairs, safely and independently. Use of the stair rail was allowed.

The NIA program consisted of 11 different exercises that attempt to isolate strengthening to important limb muscle groups in which individuals used either barbells or ankle weights with the exception of chair stand, which was done without any external weights (1). All exercises were done with the concentric action performed for 3 seconds with a

1-second pause, and the eccentric action completed during 3 seconds. Two sets of 10 repetitions were performed for all exercises. Weight was progressed in increments of 1–2 pounds.

Outcome Measures

All outcomes were measured by a research staff member blinded to group assignment. Limb strength, power, and velocity were measured using computerized pneumatic strength training equipment (Keiser Sports Health Equipment Inc., Fresno, CA). Participants were tested on seated double-leg press and seated double-triceps press machines. Seat positions were recorded and replicated at each testing session. Muscle strength was measured at each evaluation using the one repetition maximum (1RM) test as previously described (16). Limb power was measured at 70% 1RM as previously described (17). Force values represent a reliable estimate of the true maximal resistance during the repetition. At the 8- and 16-week evaluations, power output was measured at 70% of the newly determined 1RM and also at the baseline 1RM. Estimated limb velocity was calculated by the formula velocity = limb power at 70% baseline 1RM/70% baseline 1RM. Total limb strength, power, and velocity were calculated by summing the values for the double-leg press and triceps press for each participant and normalizing for body weight at the time of measurement. Reliability for strength and power testing as described earlier is excellent (1RM intraclass correlation (ICC) = 0.97; power ICC = 0.85) (17).

Functional limitations were measured using the SPPB, and by self-report using the function component of the Late Life Function and Disability Instrument (LLFDI). The SPPB is a well-established, reliable, and valid measure of lower extremity performance that is predictive of subsequent disability (12). Testing involves an assessment of standing balance, the timed 4-m walk and timed test of five chair-rise repetitions. Each of the aforementioned tests is scored between 0 (unable to perform or low performance) and 4 (high performance) and summed to a maximum score of 12. Though the initial SPPB was the test that determined eligibility, a second SPPB was performed on the first baseline visit. The average of these two SPPB measurements determined the baseline value, and single values were calculated at 8 and 16 weeks. The LLFDI is a self-report instrument designed to measure both functional capacity and components of disability (18). It is a reliable and valid measure among older adults (18,19). All the outcome measures were recorded at baseline and 8 and 16 weeks, with the exception of the LLFDI, which was not recorded at 8 weeks.

The two primary outcomes for this study were changes in impairment as measured by limb power and changes in physical performance as measured by the SPPB. Secondary outcomes included changes in limb strength and limb velocity impairments and changes in self-reported function as measured by the LLFDI.

Statistical Analysis

Statistical analyses were performed using SAS/STAT software version 9.0 (SAS Institute, Cary, NC) (20). All data were initially inspected via descriptive statistics and visually using graphic display. Descriptive information was reported as means ± standard deviations for continuous variables and percentages and counts for categorical variables. Group differences at baseline were analyzed using *t* tests for continuous variables and chi-square or Fisher's Exact Test for categorical variables. Group differences in our primary and secondary outcomes were calculated using repeated measures analysis of covariance, controlling for age, gender, and study site, which were clinically relevant covariates. We utilized an intention-to-treat analysis including all available values for participants, regardless of dropout status. Statistical significance was determined at an adjusted p value less than .025 for the two primary outcomes. Statistical significance for secondary outcomes was set at p less than .05. As part of post hoc analysis, we categorized individuals by baseline status of leg strength and leg velocity. Using measures of double-leg press 1RM and double-leg press limb velocity, participants with submedian values were defined as impaired within these categories. Group differences in SPPB performance were reanalyzed within these separate impairment categories using the same analytic approach as described earlier.

Results

Participants

Table 1 provides a description of the baseline characteristics of the 138 participants, and no significant differences were identified between groups. Baseline mobility statuses as measured by the SPPB and the LLFDI were consistent with community-dwelling older adults with moderate-mobility limitations (21).

There were 13 dropouts in the InVEST group and eight dropouts in the NIA group (Table 1 and Figure 1). Adverse events were defined as any medical event that interfered with participation in the study protocols for 1 week or longer. There were no significant differences between groups with respect to frequency or type of nonserious adverse events (data not shown). Among those not dropping from the study, one participant in each group had a noninjurious fall and 20 NIA and 19 InVEST participants required some modification of the training protocol due to musculoskeletal discomfort. Notably, three participants dropped out from the InVEST group due to influenza-related complications. One participant dropped out of each group due to

Table 1. Baseline Characteristics of 138 Community-Dwelling Older Adults Randomized to Either InVEST Training or the NIA-Advocated Progressive Resistance Training Program

	All Participants			Dropout vs Completers		
Characteristic	InVEST, $N = 72$, Mean (*SD*) or % (*n*)	NIA, $N = 66$, Mean (*SD*) or % (*n*)	*p* Value	Completers, $N = 117$, Mean (*SD*) or % (*n*)	Dropouts, $N = 21$, Mean (*SD*) or % (*n*)	*p* Value
Attendance (attended sessions/total sessions)*	.81 (.09)	.79 (.09)	.28	.81 (.07)	.73 (.15)*	.04
Age	74.7 (6.8)	76.1 (6.9)	.24	75.2 (6.6)	76.4 (8.1)	.26
Female	69% (50)	68% (45)	.99	69% (80)	71% (15)	.78
Race			.36			.36
White	81% (58)	86% (57)		85% (100)	71% (15)	
Black	16% (12)	12% (8)		12% (14)	29% (6)	
Other	3% (2)	2% (1)		3% (3)	0%	
BMI (kg/m^2)			.42			.47
Normal	32% (23)	39% (26)		31% (4)	37% (3)	
Overweight	39% (28)	35% (23)		23% (3)	37% (3)	
Obese	29% (21)	26% (17)		46% (6)	26% (2)	
Chronic conditions	5.6 (2.6)	5.6 (2.3)	.99	5.5 (2.4)	6.0 (2.5)	.95
Medications	4.3 (2.6)	4.3 (2.9)	.93	4.3 (2.8)	4.1 (2.8)	.50
Depression (CES-D score ≥16)	11% (8)	12% (8)	.75	14% (14)	12%(2)	.83
SPPB	8.8 (1.5)	8.6 (1.5)	.52	8.7 (1.5)	8.5 (1.7)	.98
Self-reported function (out of 100)	64.5 (10.8)	64.1 (10.9)	.83	64.4 (10.5)	63.8 (12.8)	.70
Limb power (W/kg)	11.1 (4.5)	11.2 (5.1)	.80	11.5 (4.8)	9.5 (4.4)	.86
Limb 1RM (N/kg)	26.5 (10.5)	27.1 (9.4)	.70	27.3 (9.8)	24.0 (10.6)	.89
Limb velocity 1RM (m-1/sec.kg)	0.018 (0.006)	0.017 (0.005)	.46	0.018 (0.005)	0.017 (0.006)	.70

Notes: BMI = body mass index; Normal (16 < BMI < 25); Overweight (25 ≤ BMI < 30); Obese (BMI ≥ 30); CES-D = Center for Epidemiological Studies-Depression Scale; InVEST = Increased Velocity Specific to Task; NIA = National Institute on Aging; 1RM = One repetition maximum; Self-reported function = function component of the Late Life Function and Disability Instrument; SPPB = Short Physical Performance Battery.

* Excludes participants who dropped out before initiating exercise protocol ($n = 4$).

muscle pain resulting from the protocols. Other than attendance, there were no significant differences in baseline characteristics of the dropouts in comparison to the completers (Table 1).

Training

Attendance for training, excluding those who dropped out prior to initiating exercise (InVEST $n = 3$; NIA $n = 1$), was 81% for the InVEST group and 79% for the NIA group.

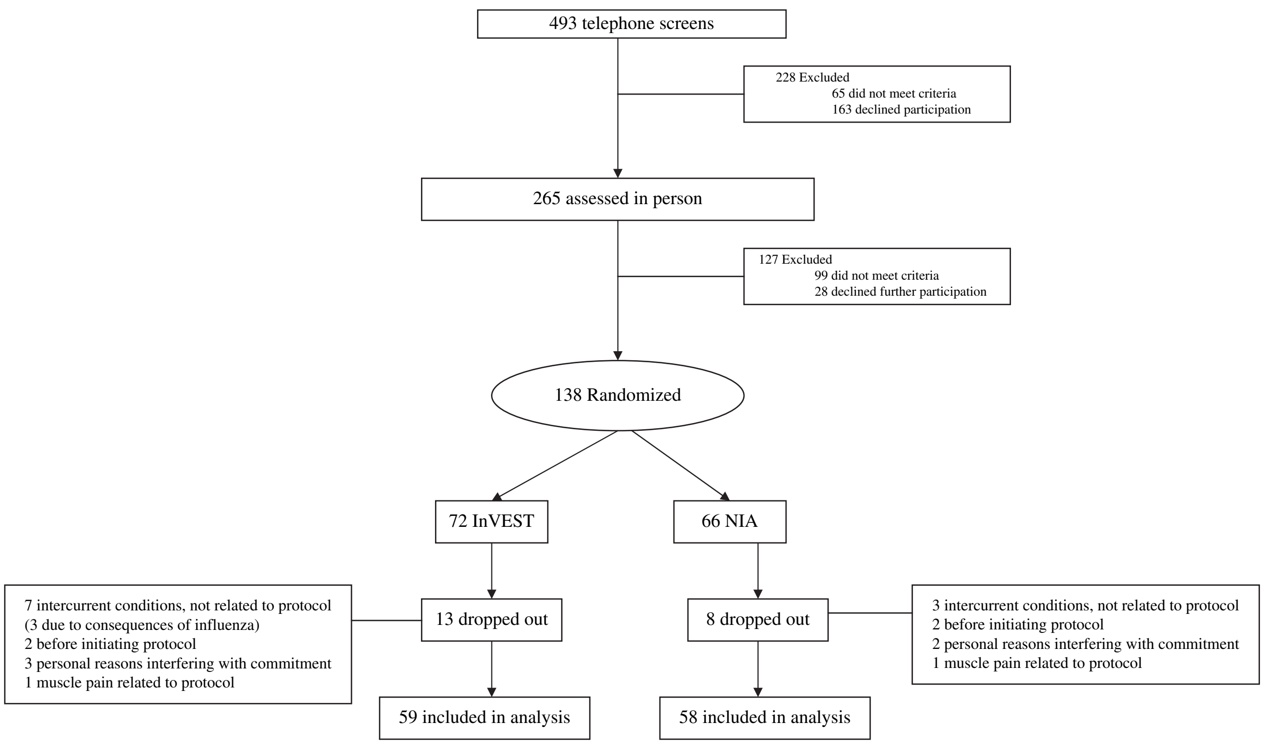

Figure 1. Consort diagram.

Both the upper and lower limb exercises were conducted within the targeted range between scores of 11 and 16 on the Borg Scale of perceived exertion (data not shown).

Outcomes

Table 2 presents findings from our analysis of changes in limb power, limb 1RM, and limb velocity after 16 weeks of training. With limb power, there was a significant Group × Time interaction observed ($p = .02$). Changes in limb power increased from an adjusted mean score of 11.1 W/kg to 12.1 W/kg in the InVEST group. After Week 16, the limb power in the NIA group was identical to the baseline-adjusted mean score of 11.4 W/kg. There were significant changes in limb 1RM from baseline among both groups ($p < .001$), though no Group × Time effect was observed. The final value of limb 1RM for InVEST (32.2 N/kg) represented a 20% change in the adjusted mean, and the final value for NIA (32.0 N/kg) represented a 19% change from baseline. Limb velocity also had a significant time effect ($p < .001$) for InVEST (.0020 m-1/sec.kg increase) and NIA (.0009 m-1/sec.kg), but no significant Group × Time effect ($p = .13$).

Table 3 presents changes in observed and self-reported functioning after 16 weeks of training. There was a significant time effect for SPPB ($p < .001$) and the LLFDI ($p = .005$) for both groups. Differences between groups in the SPPB change (1.75 InVEST vs 1.42 NIA) were not statistically significant (Group × Time $p = .44$). Similarly, differences in LLFDI change (InVEST 2.6 units vs NIA 1.1 units) were not statistically different ($p = .18$).

As part of a post hoc analysis, leg strength and leg velocity were not statistically associated (Pearson $R = .07$, $p = .44$). When categorizing individuals by the presence of these impairments, we found that 37% of participants had a velocity impairment (velocity < .00765 m-1/sec.kg), 36% had a strength impairment (1RM < 16.279 N/kg), 13% had both impairments, and 14% had neither. To analyze the impact of a strength or velocity impairment at baseline, we evaluated those with any strength impairment (strength impairment group + both group) and those with any velocity impairment (velocity impairment + both group) in separate analyses. Among participants with any strength impairment ($N = 67$; NIA $n = 31$, InVEST $n = 36$), there was a significant change from baseline in both groups ($p < .001$), but no Group × Time effect ($p = .94$) with the derived difference in improvement between groups being 0.09 units (see Figure 2). Among participants manifesting any velocity impairment ($N = 68$; NIA $n = 37$; InVEST $n = 31$), both groups also significantly changed from baseline ($p < .001$) and the Group × Time effect bordered statistical significance ($p = .05$), with the manifested difference in SPPB improvement being 0.73 units greater for InVEST (Figure 2).

Discussion

Our study reports important findings with respect to changes in limb power impairments and mobility limitation with InVEST and NIA training. As hypothesized, InVEST training did produce significantly greater improvements in limb power than did NIA. Both groups produced robust changes in observed physical performance; however, contrary to our hypothesis, the observed difference in effect was not statistically significant. However, our post hoc analyses, which evaluated participants on the basis of baseline leg impairment status, produced intriguing findings with regard to observed changes in physical function.

After 16 weeks of training, InVEST produced an approximate 10% improvement in limb power, whereas NIA had no change from baseline. This magnitude of limb power improvement is consistent with the pilot investigations evaluating InVEST training (4,11). Our secondary analyses evaluated changes in the two components of limb power, strength and velocity. Both InVEST and NIA training produced significant and similar improvements in strength from baseline (InVEST 20%, NIA 19%), which is equivalent to or greater than strength improvements observed within previous studies evaluating home-based modes of exercise training (22). InVEST produced more than a twofold larger

Table 2. Repeated Measures Analysis of Covariance Comparing Changes in Limb Strength, Limb Power, and Limb Velocity in Response to Either InVEST or NIA Training Programs Adjusted for Age, Gender, and Site

Measure	Week of Training	InVEST, Mean (*SE*), *N* = 72	NIA, Mean (*SE*), *N* = 66	Group Effect, *p* Value	Time Effect, *p* Value	Group × Time, *p* Value
Limb power 1RM (W/kg)	0	11.08 (.38)	11.40 (.40)	.66	.005	.02
	8	11.87 (.39)	11.61 (.40)			
	16	12.13 (.40)	11.40 (.41)			
	wk 16–wk 0	1.05	0.00			
Limb 1RM (N/kg)	0	26.8 (.79)	26.9 (.83)	.96	<.001	.92
	8	30.9 (.89)	30.8 (.93)			
	16	32.2 (1.01)	32.0 (1.05)			
	wk 16–wk 0	5.4	5.1			
Limb velocity (m-1/sec/kg)	0	0.0177 (0.0006)	0.0172 (0.0006)	.20	<.001	.13
	8	0.0191 (0.0006)	0.0180 (0.0006)			
	16	0.0197 (0.0006)	0.0181 (0.0006)			
	wk 16–wk 0	0.0020	0.0009			

Note: InVEST = Increased Velocity Specific to Task; NIA = National Institute on Aging; 1RM = One repetition maximum.

Table 3. Repeated Measure Analysis of Covariance Comparing Changes in Physical Performance and Self-reported Function in Response to Either InVEST or NIA Training Programs Adjusted for Age, Gender, and Site

Measure	Weeks of Training	InVEST, Mean (*SE*; *N* = 72)	NIA, Mean (*SE*; *N* = 66)	Group Effect, *p* Value	Time Effect, *p* Value	Group × Time, *p* Value
SPPB	0	8.73 (.17)	8.65 (.17)	.25	<.001	.44
	8	10.01 (.17)	9.75(.17)			
	16	10.48 (.19)	10.07 (.19)			
	wk 16–wk 0	1.75	1.42			
Self-reported function (out of 100)	0	64.2 (1.1)	64.5 (1.2)	.77	.005	.18
	16	66.8 (1.2)	65.5 (1.2)			
	wk 16–wk 0	2.6	1.0			

Note: InVEST = Increased Velocity Specific to Task; NIA = National Institute on Aging; Self-reported function = measured as the function component of the Late Life Function and Disability Instrument; SPPB = Short Physical Performance Battery.

increase in limb velocity than NIA (InVEST 11% vs NIA 5%), although the difference was not statistically significant (p = .13). A likely cause for the lack of statistical significance is the fact that velocity was a derived estimate of peak velocity, contributing to greater variability of the measure. The observed changes in limb 1RM between groups were essentially equivalent, suggesting that improvements in limb velocity accounted for the observed difference in limb power. Future studies wishing to evaluate limb velocity should consider a more optimal measurement methodology and/or a larger sample size.

The clinical relevance of these observed differences in limb velocity has yet to be determined. Limb velocity measured by our methods represents a relatively new impairment, and it is indeed statistically distinct from limb 1RM. The importance of limb velocity has been highlighted by two recently published cohort studies addressing falls (8,23). Taken together, these reports suggest that improvements in limb velocity impairments may have relevance to prevention of falls and fall-related injuries (8,23).

The primary focus of our study was the effect on mobility limitation. The observed improvements in SPPB performance between both groups (≥1.4 units) are clinically relevant, as a 1-unit difference is considered a meaningfully large clinical effect (24). Additionally, both groups demonstrated improved self-reported mobility function from baseline, with the InVEST group improving 2.5 units and the NIA improving 1.0 unit on the LLFDI. In a previous investigation of strength training among stroke survivors, an improvement of 1.3 LLFDI units was observed (25). Although consistent with our observed differences, unfortunately, clinically meaningful differences in LLFDI scores have yet to be elaborated. Despite this, inclusion of both physical performance and self-reported measures of mobility has been advocated for geriatric outcomes research (26).

Contrary to our hypotheses, we did not observe a significant difference in physical performance between groups. Differences of .28–.52 units were reported as clinically relevant small differences in SPPB performance (24). This might lend some clinical relevance to our observed difference of .33 units between groups. However, because the SPPB includes chair-rise and standing-balance tasks, it may be overly sensitive to improvements derived from both exercise programs. At inception, we did not want to bias InVEST toward SPPB enhancements in contrast to NIA. Therefore, we maintained both the standing and chair-rise elements even though it meant that elements of task-specific training were present within both interventions. Therefore, the changes observed in SPPB performance may reflect a combination of both "measure-specific" training and enhancement of global physical function. The conclusion that both exercise programs enhance mobility in a meaningful way is corroborated by our LLFDI findings.

As a universal treatment, our findings suggest that the greater improvements in muscle power provided by InVEST training offer little added functional benefit over NIA. However, our post hoc analysis provides a more refined clinical context in which the two treatments may be viewed. Leg strength and leg velocity were chosen as categorization variables because they represent the components of leg power and can be measured in many clinical settings. As manifested in Figure 2, our findings suggest that InVEST training may have an added functional benefit among

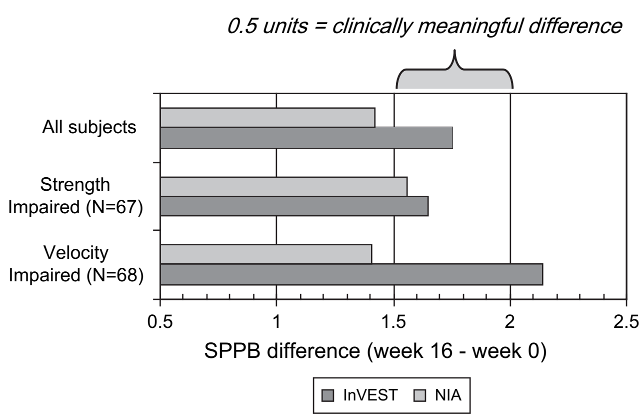

Figure 2. Difference in adjusted mean Short Physical Performance Battery scores after 16 weeks of training among participants manifesting velocity impairment (National Institute on Aging [NIA] n = 37, Increased Velocity Specific to Task [InVEST] n = 31) or strength impairments (NIA n = 31; InVEST n = 36).

individuals who manifest velocity impairments, producing an observed SPPB difference (.72) that exceeds the clinically meaningful difference reported by Perera and colleagues (24). The clinical relevance of these observed differences is emphasized when it is recognized that velocity-impaired individuals have an increased association with both falls and fall-related injuries (8,23). Though these post hoc findings surpass a threshold of a clinically meaningful effect on SPPB performance, these findings did not achieve statistical significance ($p = .05$) and should be replicated in more appropriately designed studies.

In considering other recently published exercise trials, Henwood and colleagues (27) published a study with similar aims in which they compared both strength and high-velocity equipment–based training with a nonexercising control within a smaller sample ($N = 67$) of healthy elders. They did not observe significant differences between exercise groups. Also, our reported difference in SPPB at 4 months is greater than the 1-unit difference observed after 14 months by Pahor and colleagues (28). The study by Pahor and colleagues had components of training based upon the NIA program and is noteworthy for its strong methods, large scale, and long duration (28,29). Though the study by Pahor and colleagues included long-term unsupervised exercise, for the first 4 months participants received supervised exercise as we provided. Also, the average intensity of exercise that we observed is similar (28). Unfortunately, our study did not include the 400-m walk test, a primary end point utilized by Pahor and colleagues that is linked to disability.

Our study has limitations. As mentioned previously, both strength and velocity represent estimates of the true peak values that occur during testing. Equipment capable of measuring these peak values were not utilized in this study. Secondary outcomes such as limb velocity and self-reported function require a larger sample size in order to detect statistically significant differences. Our study sample, although representative of the populations from where we recruited, was relatively homogenous racially and ethnically. From a purely physiological perspective, it may have been beneficial to ensure that the strength training program did not contain any task-specific exercises and that all training was done at high intensity (RPE 14–16) as advocated by some (30). We recognized these potential physiological limitations at inception, but felt that it was more important to view our study in clinical terms as an effectiveness trial of two potential modes of community-based exercise. Maintenance of high-intensity training may not be feasible across a varied cohort of older adults and, as demonstrated, is not required to achieve meaningful physiological improvements. Also, given its strong scientific basis and wide advocacy, we viewed the NIA program as a "gold standard" of home-based strength training and considered it the ideal comparison group. We did not feel it was appropriate to remove the few task-specific exercises (eg, chair stand) thereby misrepresenting the NIA program.

Despite these limitations, our study has strong clinical applicability. Although conducted in an outpatient center, our study design is consistent with a model of care that could be provided in a variety of community settings and might be partially reimbursed by Medicare (31). This is the first investigation to rigorously test NIA—an exercise program designed for older adults by experts in the fields of exercise science, geriatrics, and gerontology. Our study's findings corroborate its benefits for vulnerable elders and justify its development and wide distribution. Similar to NIA, InVEST did produce significant and meaningful changes in impairment and function. Both are inexpensive modes of training that can be easily translated to home settings.

The differential effects observed when baseline impairment status is considered highlight intriguing lines of future research. They suggest that, though there may be universal benefits of appropriately designed exercise programs designed to treat all individuals, more differential benefits may be observed if exercise targets an individual's baseline impairment status. Also, we conducted focus group sessions with participants who completed the study as well as those who dropped out early. In general, participants enjoyed both exercise programs. Further variation of the weekly exercises was a request echoed by participants from both groups. Having a variety of exercise choices for patients is recognized as helpful with long-term adherence and compliance (32). In the long run, incorporation of both modes of training into a clinical program may prove most beneficial, especially among fall-prone patients in whom muscle power may be particularly important.

In summary, our study among mobility-limited, community-dwelling older adults demonstrated that NIA and InVEST training produced significant changes in both observed physical performance and self-reported function from baseline, suggesting that both are effective means of enhancing function. Both groups produced equivalent improvements in strength, though InVEST did produce greater improvements in limb power. Evaluation of baseline leg velocity impairment status may identify a subpopulation for whom InVEST training provides greater enhancement in physical performance.

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Appendix 1: Vest Training Protocol—Exercise Descriptions

Weighted chair rise
- Sit toward front of chair, knees bent, feet flat on floor
- Lean back on chair in half-reclining position, keeping your back and shoulders straight throughout exercise
- Fold arms across your chest
- Raise upper body forward until sitting upright
- Stand up as quickly as possible
- Slowly sit back down
- Repeat nine times
- Rest 30 seconds, and do another set of 10

Triceps dip
- Sit in chair with armrests
- Lean slightly forward, keep your back and shoulders straight
- Grasp arms of chair, hands should be in line with trunk of body or slightly farther forward
- Tuck feet slightly under chair, heels off the ground, weight on toes and balls of feet
- Quickly push body off of chair using arms, not legs
- Slowly lower back down to starting position, pause
- Repeat nine times
- Rest 30 seconds, and do another set of 10

Toe raises
- Stand straight, feet flat on floor, in front of gym mirrors, holding onto bar for balance
- Quickly stand on tiptoes, as high as possible
- Slowly lower heels all the way back down, pause
- Repeat nine times
- Rest 30 seconds, and do another set of 10

Dorsiflexion
- Stand straight, feet flat on floor, in front of gym mirrors, holding onto bar for balance
- Quickly point toes upward as far as you can, bending only at the ankle, knees are straight
- Slowly lower toes back down, pause
- Repeat nine times
- Rest 30 seconds, and do another set of 10

Triceps press with bridging
- Sit in chair with armrests
- Lean slightly forward, keep your back and shoulders straight
- Grasp arms of chair, hands should be in line with trunk of body or slightly farther forward
- Feet are flat on floor, 90-degree bend at the knees
- Quickly push body off the chair, using your arms
- As arms are extended, use legs to lift hips up and forward so that the hips and the shoulders, hips, and knees are in a straight line
- Slowly lower body back into starting position, pause
- Repeat nine times
- Rest 30 seconds, and do another set of 10

Back extension
- Sit toward front of chair, knees bent, feet flat on floor
- Keeping your spine straight, lower your torso, bending from the hips, 45 degrees toward your knees
- Cross one arm over the other at the wrists, this is your starting position
- Quickly sit up straight at the same time, extending both arms up in the air, 45 degrees from vertical, pause
- Slowly lower to starting position and repeat nine times
- Rest 30 seconds, and do another set of 10

Unilateral stance
- Stand with right foot on a 2-in rise (block of wood) with the left foot next to the block, flat on the foot
- Stand with both legs/knees straight so that the hips are uneven, the right hip will be higher than the left
- Quickly straighten the hips so that the left foot come off the floor (both knees still straight), pause
- Slowly, keeping the knee straight, lower the left foot to the floor, causing the left hip to drop, and repeat nine times
- Rest 30 seconds, and do another set of 10

Step ups
- Stand in front of a stair or step/block of similar stair height
- Step up onto the stair with left foot, and tap the right foot onto the stair, and then back onto the floor
- Bring left foot back down to starting position
- Repeat for a total of 12 repetitions, starting with the left foot
- Repeat for 12 repetitions, starting with the right foot

Wall push-ups
- Stand facing a wall so that arms are extended straight out in front of you at shoulder level with palms against the wall and elbows straight
- Slowly bend elbows until your nose is close to the wall
- Quickly extend elbows while returning to the starting position and repeat for a total of 10 repetitions
- As you improve, move feet farther away from the wall so that your body has to travel a greater distance

Turn and reach/punch
- Stand with feet shoulder width apart
- With upper arms near your sides, bend at the elbow so that your hands are near your shoulders
- Extend your right arm across the front of your body, to the left
- At the same time, turn your body to the left, pivoting on your feet
- Left foot stays on the floor, but right heel comes up as you turn your hips and torso to the left
- Return to starting position and repeat to the other side
- Repeat for a total of 12 repetitions to each side, alternate left to right